HYDROFOIL DEVELOPMENT

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HYDROFOIL DEVELOPMENT

MONDAY, MAY 23, 1960

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
SPECIAL INVESTIGATING SUBCOMMITTEE,
Washington, D.C.

The subcommittee met at 10 a.m., Hon. Overton Brooks, chairman, presiding.

The CHAIRMAN. The meeting will come to order.

This morning we are pleased to begin a 1-day hearing on the subject of hydrofoils. As our witness today, we have Rear Adm. R. K. James, U.S. Navy, Chief of the Bureau of Ships, accompanied by Capt. James J. Stilwell, head of the Preliminary Design Division of the Bureau of Ships.

We are glad to have them here.

Tomorrow, we will have the final hearing on supersonic transports.

I might say that Gen. Thomas D. White, Chief of Staff of the U.S. Air Force, will be one of the witnesses tomorrow, and Mr. Hibbard, vice president of the Lockheed Aircraft Corp., who was sick the other day, will be the other witness.

Today we are honored to have with us from the Philippine Islands Commodore José Francisco, Admiral—what is his official title in the Philippines?

Admiral JAMES. He is Chief of Naval Operations of the Philippine Navy.

The CHAIRMAN. The counterpart of Admiral Burke?

Admiral JAMES. Yes.

The CHAIRMAN. We are delighted to have him with us this morning, and are aware of his special interest in hydrofoils.

You have a prepared statement, Admiral, and we will be delighted to have you proceed.

STATEMENT OF REAR ADM. R. K. JAMES, USN, CHIEF OF THE BUREAU OF SHIPS; ACCOMPANIED BY CAPT. JAMES J. STILWELL, USN, HEAD, PRELIMINARY DESIGN BRANCH, BUREAU OF SHIPS

Admiral JAMES. Thank you.

Mr. Chairman and gentlemen, with your permission I would like to speak to the statement rather than read it for you.

The CHAIRMAN. Fine.

Admiral JAMES. This particular development is one which we of the Navy are extremely pleased and proud to present to this group. It represents a major excursion into new technology that is intended to increase the speed of our surface ships.

It is an interesting fact of life that since man first straddled the log with a paddle and made a very limited speed by using this vehicle, that we have only progressed to speeds approximating 40 knots in the development of surface ships.

This becomes a concern to all of us who are involved in this technology of shipbuilding and design. So we have in this particular presentation the intent to present to you some of the developments which the Bureau of Ships, as the agency of the Navy responsible for design and building of our ships, have in mind in connection with hydrofoil craft.

I have before me here a model of a 110-foot hydrofoil patrol craft which represents the largest of the type ever attempted in the construction of this type of ship in the world today.

It has a particular interest to the Navy in that it gives great promise of being extremely important in the antisubmarine warfare effort. It is, as we are designing it, capable of carrying a payload of torpedoes for a considerable distance, if borne on the surface, in the order of 2,000 miles, and if it is in fact planing as a hydrofoil craft, will do this in the order of 700 miles, carrying not only torpedoes to execute a kill on submarines, but to first seek them out by the sonar equipments which will be installed.

Now, the basic problem is one of developing a new technology because, as I say, this is the largest of this type of craft that is planned for construction at the present moment around the world.

The operational techniques need to be demonstrated, and this is why we are proceeding today with the construction of this ship, so that we can, at the earliest possible moment, deliver to the operating forces of the Navy a hydrofoil craft to operationally test the concept that is inherent in this design.

The concept is such that ideally there would be two such craft operating as a team. One would be in the normal waterborne configuration, or attitude I should say. It would have its sonars just below the surface of the water. It would be listening through a pair of sonars, which will be described to you later, to detect the presence of submarines. Then a partner would be told to come up on its hydrofoils and fly to the specific location of the submarine, again to check the whereabouts of the craft and then to discharge its lethal weapons.

Now, this concept of grasshopper technique, as we call it, has not yet been proven. It is in fact a new technique and therefore needs to be operationally demonstrated.

This is why in the shipbuilding program for 1960 we proposed and received congressional authorization to construct this craft.

It still, however, is a field that has great potential. There are many many things that need to be demonstrated, however, and to be proven before we can go beyond the state of the art that is represented in this 110-ton, 110-foot craft that we are proposing to build. These include such things as determining the strength of the foils on which the craft will fly. It will involve the transmission of power from machinery or engines within the hull by right-angled changes in direction of this power to the propellers that you may be able to see here.

The CHAIRMAN. What are the foils?

Admiral JAMES. The foils, sir, are this horizontal item that you may see in the shadow here that are below. Perhaps we can show you a little better.

There is a foil forward, and there is a foil aft. If you are looking just about this location, you can see the foils that I am describing.

Normally, in surface operation the craft is simply a ship, operating at sea with this unusual configuration with it, and it carries on its stern a propeller of a standard type, except that it can be raised and lowered from the surface as appropriate to do.

Now, the research work that must be done to get beyond this 110-foot, 110-ton limitation today is really tremendous. We have got, as I say, to develop this transmission of power in these greater powers, through this configuration of right-angle bends until it finally is transferred to the water.

The strength of foils, the development of the lightest conceivable structure of the ship, itself, all of these are unique research problems which the Navy must expend considerable effort on to insure that we can get these ships up to tonnages considerably greater than the present limitations.

Now, being a ship, we have another minor problem. Shipbuilders traditionally are very conservative people. They build ships with considerable margins of safety, and in doing so, have become habitually the designers of craft of large structural dimensions and of great strength that are not appropriate for this kind of a craft, which is in fact a composition of aircraft techniques as well as shipbuilding techniques.

So in the program for the award of this specific ship, which will be awarded shortly here this fiscal year, we have invited the participation of the aircraft industry, seeking from them the infusion, if you will, of the light structures that they are so experienced and capable in developing into the shipbuilding fraternity. We have actually invited aircraft people who have waterfronts to submit bids. We have asked aircraft companies who do not have waterfront facilities to join with shipbuilding corporations that do have such facilities in an effort to achieve, as I say, an injection of the light-structure type of techniques of the aircraft industry into the high-developed, skillful shipbuilding character of our industry today.

This is the specific problem of the PC—H, as we call this, patrol craft hydrofoil, which we are about to contract for.

We also have some major problems that we need to concern ourselves with, and this is what led us into the hydrofoil craft. I mentioned the relatively small change in speed from the man on the log to the finest of our ships today, in the order of from a knot to in the order of 40 knots, and we believe we can achieve one of the basic and fundamental facts of life that prevent us from getting high speeds in ships by going to hydrofoils.

By this device, actually, we have a ship that is flying in this attitude, as represented by the model, on aircraft section-type foils.

In this attitude, the ship eliminates the wavemaking and skin resistance that are the major elements today that deter a ship, no matter what its power, to achieve while operating on the surface the kind of speeds that are possible.

Flying in this attitude, then, we have a relatively small problem of resistance, and hence we are able to anticipate the development of

much greater speeds. We do this by a variety of foils, and later my associate, Captain Stilwell, will describe these for you in detail.

The kind of foil you see here today we call a submerged foil, in that it remains continuously submerged below the surface of the water.

It was possible only after we were able to develop the means to control the angle or the attitude of that foil so that the ship could fly at the surface of the ocean and changes by the wave motion of the surface, and this was achieved only relatively recently.

I could mention that hydrofoils, themselves, are anything but new. The concept goes back to before the 20th century.

The actual first successful hydrofoil craft of any note was designed by Alexander Graham Bell, who has many other achievements to his credit. And he, with his Canadian associate, Mr. Casey Baldwin, developed a hydrofoil craft that actually, as we call it, flew at 60 knots, this in 1918.

But there were still problems of control of these craft that have not been successfully licked until quite recently.

In 1947, concerned with this problem, one of the gentlemen, who happens to be present as a spectator today, Adm. Armand Morgan, formerly Assistant Chief of the Bureau of Ships, assisted in having this control problem brought to the attention of industry, and a successful small craft, I believe about 36 feet, was designed and built, which showed the capability of exercising proper controls for these foils, which gave promise then of having a craft that could remain above the surface of the ocean as the wave configuration, itself, which is constantly changing, strove to knock it down.

This is why, then, we had to wait until that achievement before we could proceed into the construction of this relatively large ship which we are proposing to build today.

Hydrofoils also have found considerable interest in foreign countries. The Italians have been very uniquely interested in this program. And a corporation, the Rodriguez Co., down near the Straits of Messina, have manufactured successful hydrofoil craft, generally of small size, and scarcely ever over 25 displacement tons, that are operating in many places around the world.

The Swiss have a very successful hydrofoil craft operating on Lake Lucerne.

The Rodriguez people built a hydrofoil that came to the Western Hemisphere and has been, until recently, operating off of Puerto Rico.

These craft have largely been used for passenger service. They give quick transmittal of people over long distances and are largely, at the moment, involved in that kind of service only.

But it is not the only potential of this particular design. The hydrofoil has many applications. One of the interesting facts of a visit that I made to the Far Pacific in visiting the Philippine Islands last January, an old friend of mine from Naval Academy days, now Commodore Jose Francisco, Chief of Naval Operations out there, showed keen interest in this program, and I think that is what inspired him to take time out from his SEATO duties to come here today.

The CHAIRMAN. I promised him that you would be able to reach the Philippine Islands from the United States in 4 days. Did I exaggerate too much?

Admiral JAMES. No, sir, but we aren't selling tickets yet. [Laughter.]

I trust the commodore has provided other means of transportation if he is going home soon.

His keen interest is because in some of the more remote islands they have a problem not unlike that which we faced during the days of prohibition, running in illicit merchandise. The use of a craft of great speed would be of considerable interest to the Philippine Navy.

There are other potential commercial uses. For example, I can conjure up the fact that the transshipment of bananas from some of our Central American Republics might be accelerated by the use of hydrofoil craft where they did not have to invest great cost and weight in the installation of refrigeration space to hold this rather critical cargo. And items of this sort are on the threshold and beyond the horizon of the moment, but they are certainly in the area where these kind of developments are important to the world.

We are not alone in our interest in the U.S. Government in hydrofoil craft. The Maritime Administration has planned and is already underway in the construction of what I believe is an 80-foot hydrofoil craft that will reach speeds of 60 knots or greater.

We have been a technical adviser with the Maritime Administration, have kept in close contact with their programs.

The Canadians likewise have engaged in an effort to exploit this new principle, and we are distilling all of this kind of experience and information that we can into our own efforts that will be put into larger ships as we proceed, than the one that you see before you.

We aspire in our research and development effort, as the next step, to build, in fact, a research craft, a hydrofoil research craft, where many of these uncertainties that would shove ahead the frontiers of this technology can be developed. And we are already presenting our requirements to the people in charge of the Navy and the Department of Defense technical research programs to recommend immediate initiation of programs that will permit us to come back in a relatively short time, I am sure, and recommend to the Congress the construction of craft in the order of 250 or 300 tons, maybe even larger.

These are definitely new frontiers that exist, but they are things that have to be done if we are to achieve technological supremacy over the nations of the world who have navies, and we believe, therefore, that we should pursue this program with the greatest of enthusiasm.

There is one other area of high-speed craft that I would be remiss not to mention. It is, however, a subject different from what you have asked us to talk to today, and I will simply mention that the Navy is also engaged in what we call a hydroskimmer program, differing from the hydrofoil craft, which is supported, in fact, by the wing structure that you see here, a hydroskimmer would float on a cushion of air.

It has a lot of land counterparts that I am sure you gentlemen have been exposed to in various presentations you have held in the past.

We are trying to exploit this new technique in ships, and it has a great potential in that you can go to much larger tonnages of ships with this air cushion to support the craft and to propel it than does the hydrofoil promise us today, but, as I say, this is a completely new subject, and I would prefer, therefore, to simply mention it as I have.

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Our interest in hydrofoils at the moment is purely military, for the application of this technique to whatever uses the operating forces of our Navy see fit and promise in it, and we are hereafter pressing forward to resolve all of these problems.

Now, the program is one that we have a great deal of detail that I think would be of interest to you.

We have an additional program of some slides and a few feet of film to show you the state of the art as it has progressed since the beginning of this century.

I would like at this time, with your permission, to introduce Capt. James Stilwell, who, himself, has been intimately associated with this program in the Bureau of Ships since 1948, and in fact, is our senior officer who has been, to a major measure, instrumental in much of the development work that he will show you hereafter.

The CHAIRMAN. Now, is it your pleasure, Admiral, to have these slides at this time?

Admiral JAMES. As you will, sir. But Captain Stilwell will pick it up. He has some more material.

The CHAIRMAN. Do you have a statement to make, Captain Stilwell?

Captain STILWELL. I have no prepared statement, sir.

Actually, my remarks will go with the slides and the movie, as appropriate.

The CHAIRMAN. Then why not proceed, Captain Stillwell, with the slides, and you can make your remarks or interpolate as you go along.

Captain STILWELL. All right, sir. I have a few introductory remarks here. I believe Admiral James has introduced you to the subject very adequately.

However, to expand a bit on the principle of the operation of hydrofoils, I think most of you are quite well aware of the principles under which an aircraft flies. The fluid in the case of aircraft is air. In passing over an airfoil shape, it creates a negative pressure on the top surface and positive pressure on the bottom, which gives lift and supports the weight of the craft.

Water, up to certain speeds and under most conditions, is precisely the same type of an actor, as far as the fluid goes, as air, so that you can take precisely the same shapes of airfoils that are used to support aircraft, put them in water, and they will generate lift in exactly the same way, the biggest difference being that water is about 600 times as dense, hence the area of foil required is that much smaller or gets much greater lift for the same area and speeds.

In the hydrofoil craft, then, we have two methods of support. The hull must be able to float in the at-rest condition and during takeoff.

This, incidentally, has a great deal to do with the shape and configuration of the hulls of hydrofoil boats, in that, as a general thumb rule, they take off, similar to the aircraft use of the term, at about half of their top speed. So, say you have a craft that will fly on hydrofoils at about 60 knots, she would be expected to leave the surface of the water, as far as the hull goes, at about 30. So that you will design your hull to achieve its minimum resistance at about this speed, consistent with other factors, so that the total resistance of the foils and the hull are a minimum at this point.

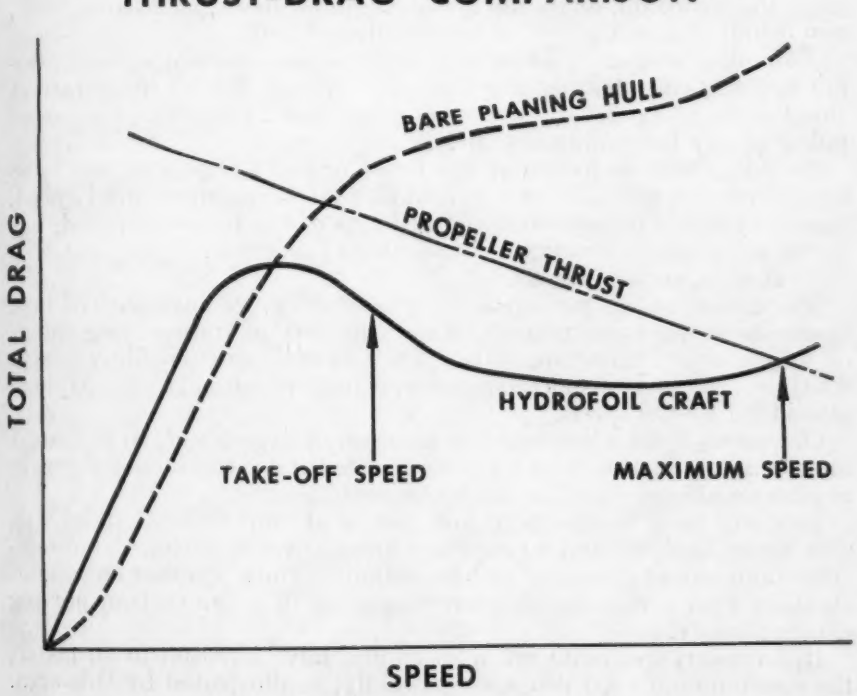
Incidentally, this is one of the critical design points in designing this type of craft, to be able to get her out of the water. Once the hull is

clear, the resistance drops rather markedly for a period until you get to higher speeds, where the resistance again builds up.

The peculiar item that makes the hydrofoil boat perhaps much more difficult a problem than the aircraft is the fact that it is flying in a very restricted altitude band. Actually, as Admiral James has mentioned, the hydrofoil principle was started and tried out about the same time as early aircraft. The aircraft obviously have gotten to the answer a lot more quickly than the hydrofoil, the reason being, as I say, that the hydrofoil must fly in close proximity to the water surface, and the relative vertical control required to do this is a much higher degree than required in altitude control of aircraft, plus the fact that the surface of the water or the reference plane from which we must control is forever, in most cases, a rough surface and an unpredictable surface. So you must have some way of measuring its position and keeping these foils at a reasonable depth below this surface. From this stems most of our basic problems, problems that have followed the inventors of this device since its early days.

Now, if I may have the first slide (fig. 1), please.

FIGURE 1



You might ask why we are interested in the hydrofoil and how it compares with other means of locomotion.

You will notice this total drag—in effect it is how much power you need to push yourself through the water, how much resistance the craft has, as speed increases in this direction.

As I have indicated, at rest, of course, floating in the water, it requires no power. As you start speeding up, the hull itself makes resistance in pushing the water aside. There is also drag on the wing structures. So you build up your drag rather rapidly to a hump. Just shortly after you have reached this hump of total resistance, the hull leaves the water, the craft is supported on the foils which are below the water, and this resistance drops down to the drag of the foils and struts, themselves. This continues fair'y level for a time and starts climbing out in here until you reach the limit of your installed power, and this becomes your maximum speed. This is a typical curve of not any particular hydrofoil, but most hydrofoils follow this pattern.

For a comparison here, I have included a curve which shows the typical resistance pattern of a planing craft.

Now, the planing craft is perhaps the closest conventional type to a foil in operation. Actually, a displacement or conventional craft would be worse in this comparison than the planing craft. You will notice its operation is a general increase, until it gets up on the step, which is the usual term for planing craft, then its resistance drops off for a bit and continues to increase as higher speeds are reached.

But you will note that for this speed range that we are talking about here, the hydrofoil, at its top speed, requires about, as a thumb rule, about half as much power as a conventional craft.

You might also note, if you look at the lower speed range, the hydrofoil requires considerably more power. If you wanted to operate at this low speed range, the hydrofoil might use 25 to 30 percent more power than a conventional craft.

So this points us to one of the fundamental things that you must agree to before considering a hydrofoil, that is you must need speed, because you are paying for speed in terms of the power installed, but if you want speed, this is the cheapest way to get it.

Next slide, please (fig. 2).

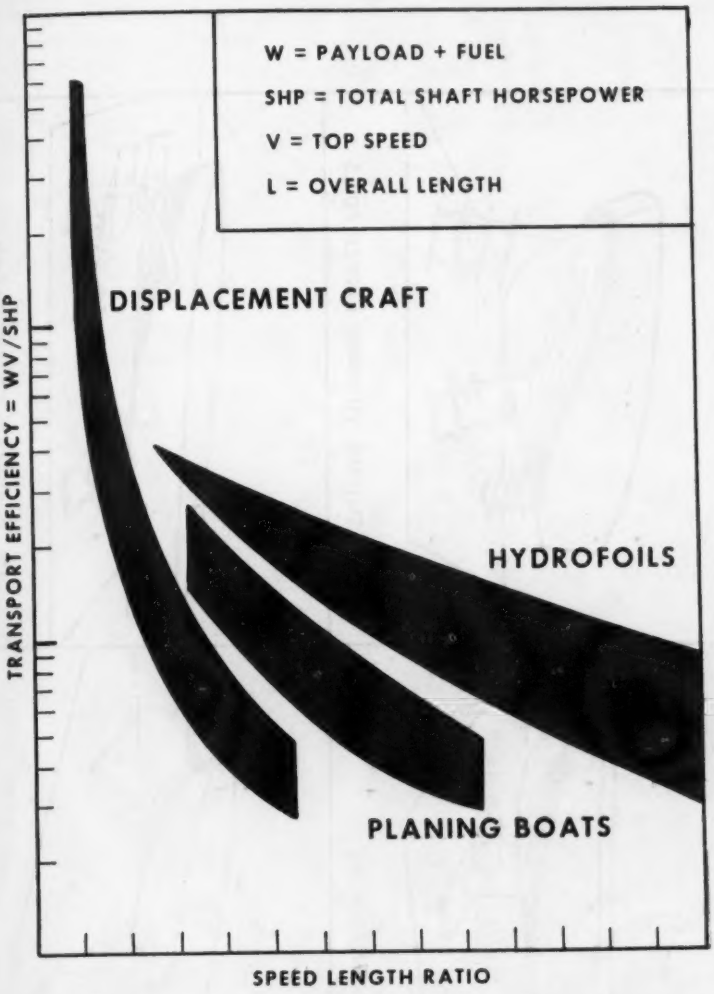
To emphasize this perhaps a little more fully, we have plotted here the areas of what you might call the efficiency of transporting things or people or military capability. On this scale on the side we have what we call a transport efficiency, which is actually the payload multiplied by the speed.

Of course, it costs you more to transport things faster, so you must include speed in this, and we have divided it by the installed power to give an idea of which is the better craft.

You will note at the very low speeds of conventional freighters, slow-speed tankers, and so on, they are many many times more efficient than any of these craft we are talking about. So that we cannot compete with a slow-speed conventional craft as far as transporting things cheaply.

If, however, you build up in speed and have a reason to go faster, the conventional craft drops very rapidly, as illustrated by this area.

FIGURE 2



You will find that planing craft and faster types of conventional craft fall in a middle position, and hydrofoils are much more efficient as you get out into the higher speed. This is true for most of the speed ranges that we are talking about.

Next slide, please (fig. 3, p. 10).

Now, we have indicated that this control problem is one of the knotty ones. Actually, it divides the hydrofoils into their basic classes, of which there are four.

One we have discussed here and you have seen in PC—H, the most recent development, the submerged foil. Just a few words about its characteristics:

The foil or lifting surface, as indicated here, being beneath the surface, really doesn't know of itself where the surface is, so you must supply some means of measuring the distance from the hull to the surface of the water, transmitting this information in a processed form to the foil and telling it what to do, to come up or go down.

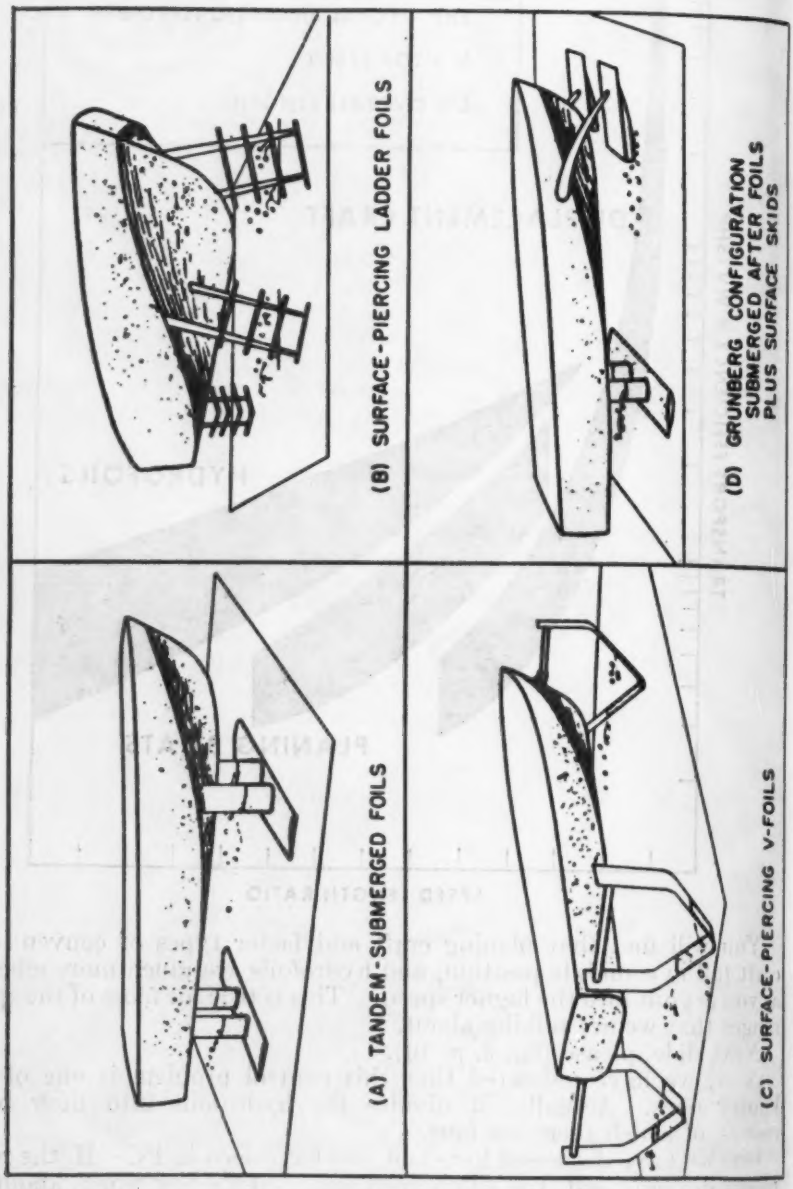

(A) TANDEM-SUBMERGED FOILS
(B) SURFACE-PIERCING LADDER FOILS
(C) SURFACE-PIERCING V-FOILS
(D) GRUNBERG CONFIGURATION
SUBMERGED AFTER FOILS
PLUS SURFACE SKIDS

FIGURE 3

This, of course, as Admiral James has mentioned, is one of the breakthroughs of fairly recent date, which has made this craft possible.

Earlier craft—as a matter of fact, the first ones that were at all successful, were the surface-piercing ladder-foil types. This is a much simpler device, in that you arrange these lifting surfaces—in this case there are a number of them—like Venetian blinds, along a strut going into the water. The water surface comes across here [indicating]. If, for instance, your craft is either going too slow or it is too heavy, it tends to fall, the surface of the water creeps up this configuration and picks up more lifting surface. That oscillates back and forth until the amount of lifting surface under the water is just enough to support the weight of the craft.

This is also duplicated aft, so that you have a control on both ends of the boat, and it is an automatic control. It has some drawbacks, which I will come back to.

Another means of achieving this same thing is to shape your lifting surfaces or foils into a V or U shape. So that the surface of the water, in rising and falling along this V shape, picks up or more or less lift as required, and you come out to equilibrium where the amount of foil area under the water is just enough to support the craft.

Here again you have the same idea forward and aft, so that you get a trim control as well.

Another and perhaps more interesting way of doing it is to have a submerged foil aft, which is similar to these except that it is fixed and cannot move with relation to the hull. Then you put a couple of slippers or skids under the bow which always stay on the surface. The craft itself acts as a control lever, you might say. If the craft is too heavy or going too slow, this foil sinks into the water; it is not producing enough lift to hold you up, and you start sinking. However, your slippers stay on the surface, so the craft, in effect, turns, which makes a higher angle of attack on this foil here, which causes it to pick up more lift and support more weight to bring the stern back up. So that this is, in effect, an automatic control of a submerged foil, using the whole craft as the lever. This one is called the Grunberg configuration, this the V-foil configuration, the ladder-foil configuration, and submerged-foil configuration.

Just a few words about how these operate:

One of the Achilles heels that has plagued foils from their inception has been their performance in a following sea. If you will think for a moment what happens in a following sea, you are proceeding through the water and depending for lift on the speed and the angle of the flow past this hydrofoil. Now, if you get into a situation where waves are coming up to you from the stern, there is a rotary motion in the wave which has a forward velocity. It also has a downward velocity as this rolling motion of the wave approaches you. So what happens, when it gets to the foil, you get a decrease in your angle of attack, because this wave is coming over and superimposing its own flow on that which is going by from your forward speed, which means you are getting reduced lift. Also, the speed of the wave subtracts from the speed of your translation through still water, which gives you less flying speed, which tends to, again, reduce your lift. So that unless you are able to make a major change in your angle of attack or a major change in speed, you are apt to lose sufficient lift to keep the

(C) SURFACE-PIERCING V-FOILS

hull out of the water, in which case the hull comes down, contacts the water; you have to go through a takeoff procedure all over again.

This has been a problem with most of these configurations, particularly with the V–foil configuration, the ladder-foil configuration, and to some extent with the Grunberg configuration.

Fortunately, the submerged-foil configuration has a much higher capacity for changing its lift, and today, at least, in the sizes and speeds at which we have operated, this has not been a problem. The reason I think is, geometrically you cannot build surface-piercing configurations so that you can vary this lifting surface more than about 2 to 1. You can build in about twice as much lifting surface as you need to take care of this type of eventuality. In a characteristic of a submerged foil, by changing its angle in a controlled manner, you can perhaps change it as much as 4 or 5 to 1 and have that much more gravy to keep yourself from falling into the water.

Off slides, please.

Around these general classes of foil boats, to go back into history, Foralani, back in 1898, had a fairly successful ladder-foil boat. Not too much was done with it for a bit. However, about 1907, the Wright brothers, in this country, got interested in foil boats, did some investigating, and then a little bit later, about 1911, Captain Richardson, Navy, in this country, and Gudoni, in Italy, further worked in surface-piercing and ladder-foil boats, and as the admiral mentioned, in about 1918 the first fairly startling craft was developed by a group of people headed by Dr. Alexander Graham Bell. This was tested up in Boedeck Bay, in Canada.

Incidentally, of note, it was a motorboat speed record holder. It made 70.8 miles per hour, I believe. It was an 11,000-pound craft and, again, a ladder foil, probably the simplest way of doing the control. It was run by Liberty aircraft engines, a pair of them. It was quite successful.

A little bit later, in about 1934 through 1937, in Europe interest quickened. Grunberg invented this configuration I mentioned with the skids forward and submerged foil aft, in about 1934, and had a successful boat in this configuration.

Tietjens, in Germany, and one of his cohorts and disciples, Von Schertel, developed the V-foil, first in a loop-circular form, and then in a more pronounced V, and this Von Schertel configuration, we call it, was the predecessor or the father of practically all of the German, Italian, Swiss, and Dutch configurations you see today. Nearly all of them are variations of this V-foil, Von Schertel's basic configuration, taken in competition with and in conjunction with Tietjens'.

All in all, during the latter thirties and during World War II, this Von Schertel configuration was developed through about seven boats, up to a size of 80 tons. Several of them have been quite successful.

The 80-tonner was lost at sea through a grounding incident. There are various stories connected with it. Some people maintain that it had had trouble in a following sea, but I think the full facts bear out that it was a grounding.

The problems of Germany during the latter part of the war pretty well terminated the developments. They were picked up after the war with exactly the same type configuration by the Swiss company, Supermar, Ltd., and more recently by Rodriguez in Italy, and as Admiral James has mentioned, there are several ferry boats from

Venice to Trieste, across the Straits of Messina, on Lake Lucerne, Lake Maggiori, up until recently in Puerto Rico in interisland service. There have been several proposed, stemming from this same general family of craft.

One of the first people to come forth with a submerged foil was an English inventor by the name of Christopher Hook. He did not have access to electronics, however, he recognized the importance of using a submerged foil and its higher capacity of taking care of a seaway. So what he did was to hook up a submerged foil with a set of levers and at the end of these levers was a float that stayed on the surface of the water. So if the boat went down too low, the levers increased the angle of attack on his foils and gave him a controlled submerged foil boat, which, incidentally, even in a small 9-foot size, was a most startling performer, compared to any of the other craft that had been used prior to this time.

One other note of interest, as you go through a rough sea with a surface-piercing-type foil, you get a motion similar to perhaps going down a rough road, in some cases, or more gently in others, depending on the design of the craft. But when you get to a submerged-foil boat that is not precisely attached to the surface, this ride smooths out and actually, in a well-designed boat, can get to the point of near boredom. You don't even get much of a sensation of speed if your boat is designed properly and is operating properly.

This brings us down to about 1947, when the Navy Department, Bureau of Ships, and the Office of Naval Research, with some assistance from the then Bureau of Aeronautics, made a rather broadside attempt at investigating this foil business.

In a series of small craft and research and development projects we attempted to find out, first, what had gone wrong with this concept over these many years, why we didn't have hydrofoil boats, since their promise was so amazing, and what could be done about correcting these deficiencies and doing an engineering and scientific job of designing and building hydrofoil craft for a number of possible uses in the Navy.

If I may have the next slide, please (fig. 4, p. 14).

This is a picture of the model that you have seen here, which is the XCH–4, which is, surprisingly enough, one of the first projects as far as test craft that we got into. We built a small radio-controlled model of this, after considerable testing and help from NACA data and a contractor who had had NACA experience.

After a success on this small model, we built about a 7-ton craft which, as you see, looks very much like a flying boat as far as the hull goes.

From these two struts came down a series of ladders. If you will note, these are a little bit more refined than anything you have seen before this, as the ladders themselves were V-foils and did give us shock-absorber action. As the tip of one left, the beginning of the next one would come into the water, and you didn't get this sharp staccato-type shock of going up and down a series of Venetian blinds.

And the tail had a simple stabilizer you might liken to an aircraft stabilizer, which just held the tail down, surprisingly enough.

It had a pair of aircraft engines, and ultimately this one was successful in operating in smooth water at about 75 miles an hour, which was quite a breakthrough for this type of configuration at the time.

56457—60——3

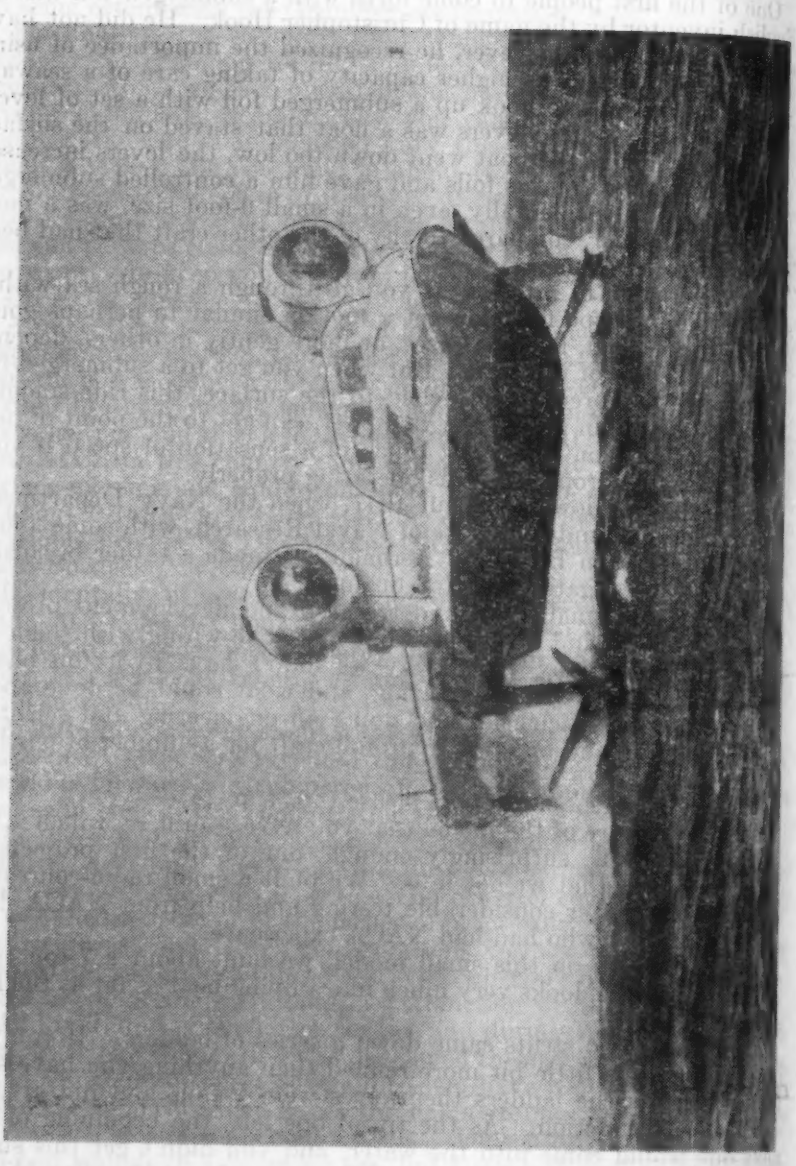


FIGURE 4

The CHAIRMAN. Is that nautical miles or statute miles?

Captain STILWELL. Statute miles.

Incidentally, you will probably find of note that inventors and other development people like to measure their speed in miles per hour, and then you have to meet the facts of life and talk about knots and nautical miles. It sounds much more startling in miles per hour, though.

This one (fig. 5, p. 16) is what we call *Hi-Pockets*, again developed by a Navy contractor in conjunction with the Bureau of Ships.

If you will note, it is equipped with the V-foils that I mentioned, surface-piercing foils, in this case four of them, one on each corner.

This particular shape of foil, which came up at a 45° angle, was considerably different than the Von Schertel configuration, which the Europeans were using and proved to be quite a bit better in a seaway.

Actually, I have personally—you can see me there—driven this thing through—variously reported as 5- and 6-foot seaways, down off Pensacola. This is rather startling when you consider this is about a 22-foot open boat, with just a125-horsepower Chrysler Crown. We made up around—well, converting to knots—about 34 to 35 knots.

She was the most successful V-foil boat that had come along to date, and led us to further developments in this direction. However, she still had her limitations in a seaway, as I have indicated before. You could always find a big enough following sea that was too big for this type of V-foil.

This is a picture of the hydrofoil which I mentioned was the invention of Christopher Hook in England. You will note these floats or slippers, that I mentioned before, go through a series of levers. This was the first successful submerged foil boat (fig. 6, p. 17).

As I also mentioned, it was a startling performer. I think this one was actually 9 feet long, and we were able to operate it in about 3-foot waves without any trouble at all.

We liked this so well that we developed it further (fig. 7, p. 18). This is a test craft which was developed under Navy contract to do a little more sophisticated job of it.

We also provided retraction to see if we could get rid of these foils when they were not wanted in shallow water, approaching beaches and things like that. That accounts for some of this Rube Goldberg type of mechanics here on the stern.

This craft was further developed to what we call *Halobates* (fig. 8, p. 19), which is the biggest test craft that has been successfully operated to date, as a test craft in submerged foils. This grosses out at about 15 tons.

You will notice here the absence of, as Christopher Hook called them, Jockey Arms. We attempted to do this electrically. So this is a test of how to control the submerged foil electrically and was limitedly successful at that time.

About this same time, speaking now in the early 1950's, Dr. Vannevar Bush got most interested in hydrofoils, proposed them for ocean transport and various other uses and formed, with some of his associates, the Hydrofoil Corp. at Annapolis; since then not in operation but most active in this time span (fig. 9, p. 20).

FIGURE 5

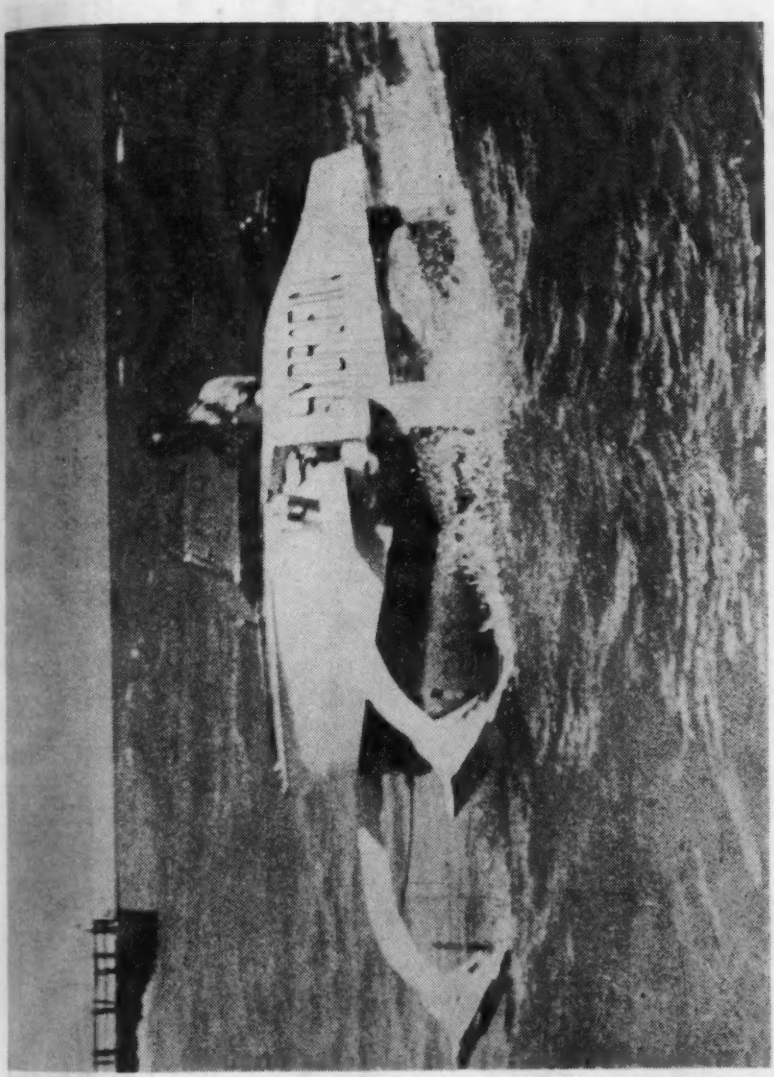


FIGURE 6

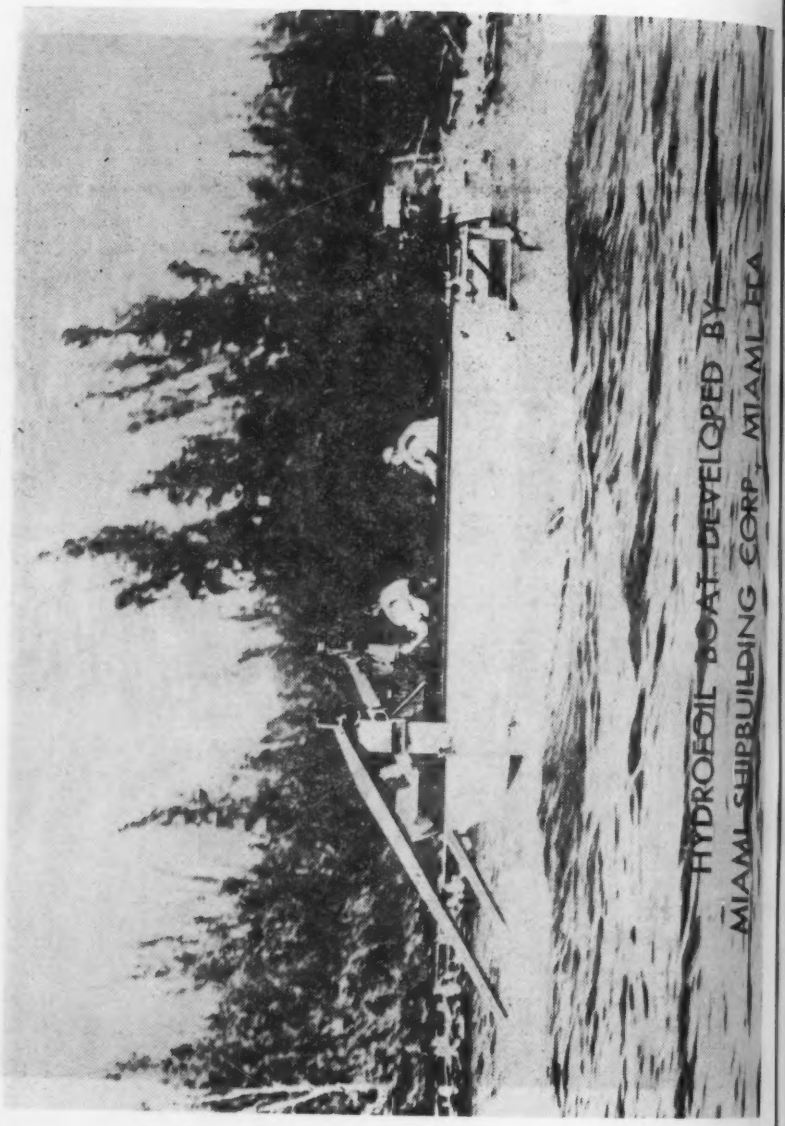

HYDROFOIL BOAT DEVELOPED BY
MIAMI SHIPBUILDING CORP., MIAMI, FLA.

FIGURE 7

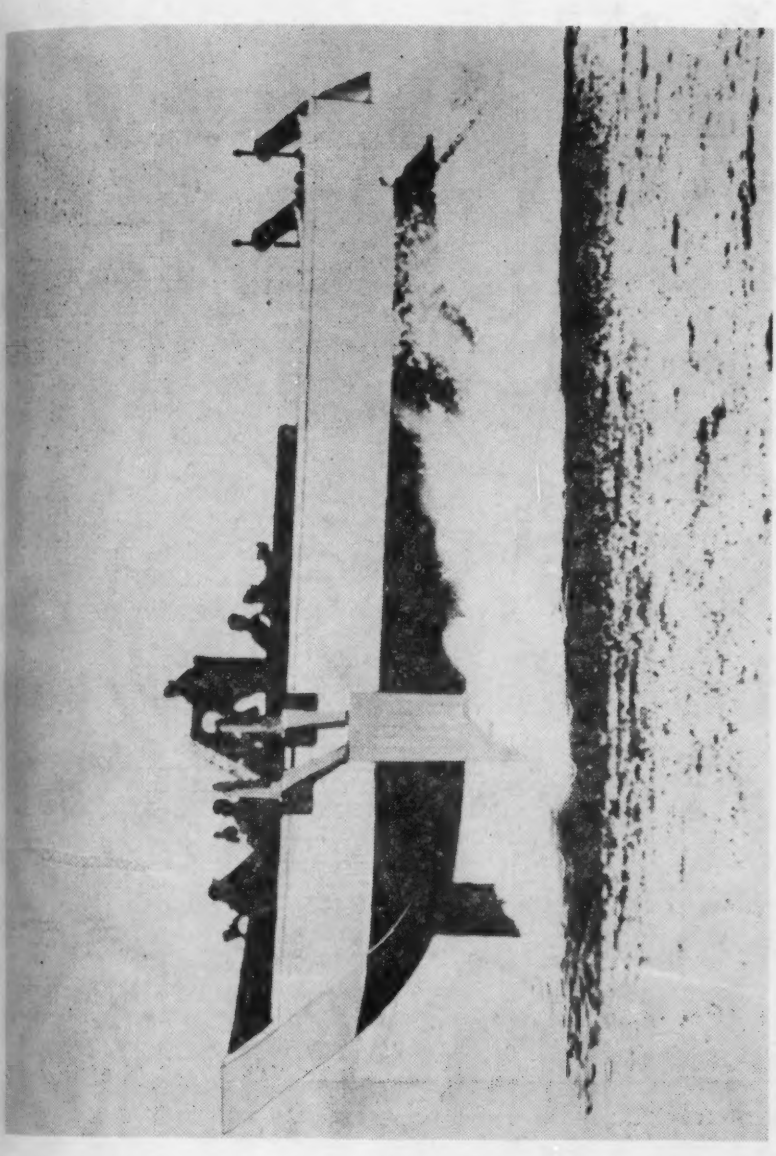


FIGURE 8

MIAMI SHIPBUILDING CORP. MIAMI, FLA.

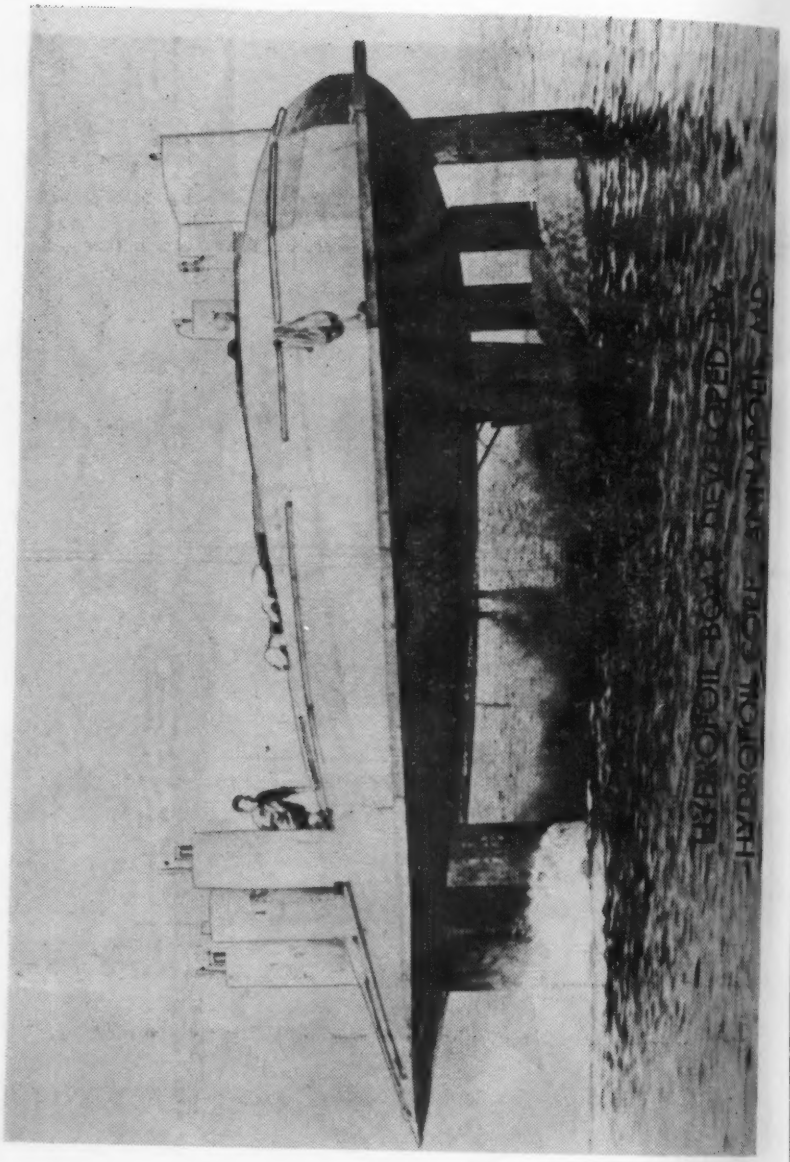


FIGURE 9

This final product was *Lantern*, which is shown here, and turned out to be about a 20,000-pound craft, and flew on a pair of submerged hydrofoils that were controlled by a pickup that measured the height of the water and was controlled in attitude and pitch by an autopilot.

As far as I know, this is the first time a hydrofoil craft used an aircraft autopilot to fly straight and true.

This craft was underpowered for its size and had various troubles, although it was most helpful in its development in proving out certain concepts of submerged-foil operation.

Its demise occurred when a crane operator dropped a hook on a 15-ton crane through the plywood hull.

Another contractor was used to develop a test bed for this control problem that we have mentioned. This (fig. 10, p. 22) is a 20-foot aluminum—you can call it a boat, I guess. Basically, it is a pair of aluminum beams with some plate around to keep the water out, so that you can put struts at any place you want, carry sufficient instrumentation and sufficient power in outboard motors to investigate various ways of controlling foils.

This craft was a workhorse in the mid-fifties. In cooperation with MIT Flight Control Lab the Navy and our contractor's engineers developed an original breakthrough of a new device for measuring the water's surface and converting this into a control signal to control the foils.

This resulted in *Sea Legs*, which, to date, has been the most successful submerged-foil craft built (fig. 11, p. 23). It is built as a test craft, although it does look somewhat like a pleasure boat here.

It has its main support aft, in a large submerged foil, which can be controlled, has a small stabilizer foil here to control its pitch.

This is the black box that measures the height to the water and transmits it back to the foils.

This one is the one I mentioned, where you achieve the sensation of boredom. In most seas that this craft will operate, you get no sensation of flight or speed at all.

A logical development of this and the rest of our experimentation and research was the PC—H, which you have seen the model of (fig. 12, p. 24).

You will note here its configuration is similar, with the large foil aft, the stabilizer forward. Again we hope it will have—we predict it will have the most excellent sea-keeping capabilities of any craft of its size.

If I could have the lights back up just a second.

I have mentioned several times this sea-keeping proposition. This does place a limitation on hydrofoils in terms of speed and size. If you have a given seaway to overcome, there are two ways of doing it: One, getting large enough to get well above the sea, or to get fast enough to outrun the sea. So that the design of a given hydrofoil will depend on more or less of a tailormade job to a given sea state until such time as you are ready to design a large enough and fast enough one that can ignore seaway in general.

One other limitation I would like to mention, because it does have a profound effect on the future, at least, of hydrofoils, is something that has plagued the aircraft people from their inception also, which we call the cube-square law.

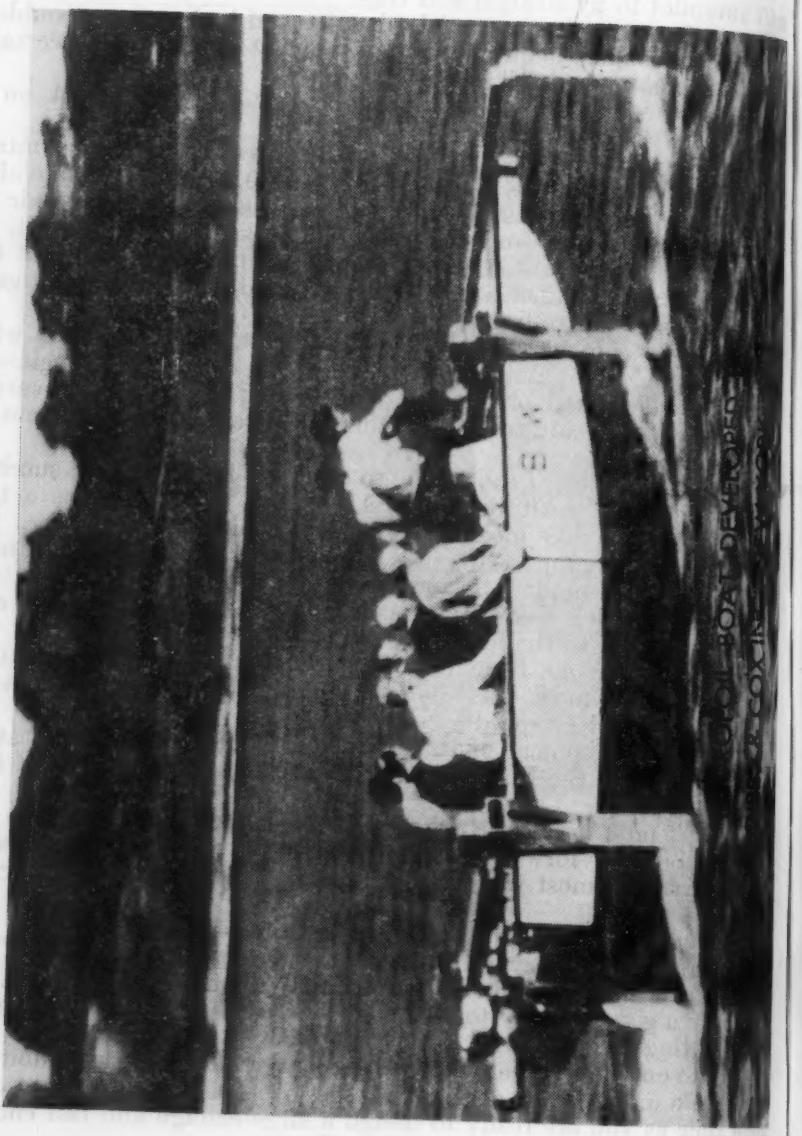


FIGURE 10

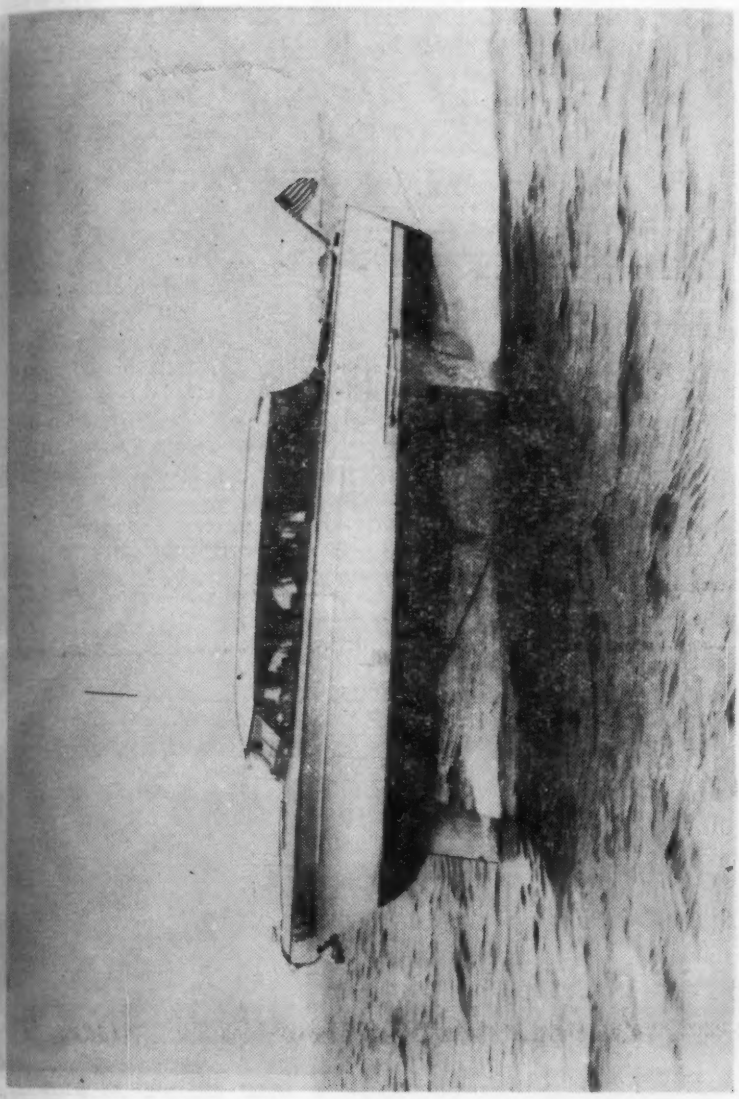


FIGURE 11

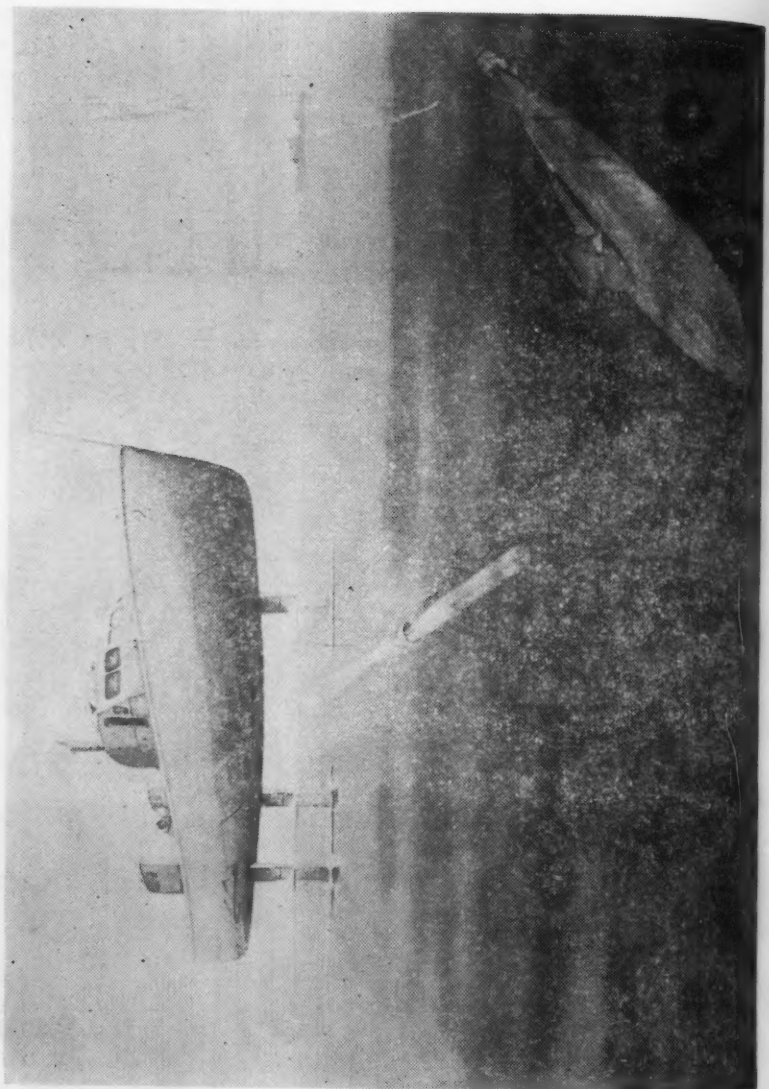


FIGURE 12

The lift of a foil, its dynamic lift, depends on various things, one of which is the area of the foil, or the area of the wing. Unfortunately, however, the weight of a vehicle, supposing it is of normal density, or that you use the space that you build into it in a normal manner, the weight increases as the cube of any principal dimension. Say a boat that is twice as long as another boat will be about eight times as heavy. However, if you put on a suit of foils on this boat that is twice as long as the other, you would only be able to get, without change of geometry, the square or four times as much area. So you would have ended up with a boat that weighs eight times as much and be supporting it with something with only the capacity of picking up something four times as heavy. So this general law means that as you get bigger, the foils—this is with constant speed, of course—the foils must get bigger proportionately to the hull. This introduces the problem of either increasing the drag by putting more supports down to hold the hull up or by getting much stronger material. So it poses a size limitation.

Just where this occurs with existing state of the art or existing materials is a little hard to say at the moment. We are confident that we can build a 100-ton craft, and we have proposed, as Admiral James mentioned, a research craft of about two and a half to three times this size, and we would perhaps at that time be in a position to look forward to one even larger, but we certainly aren't talking in hydrofoils, at least, with any known or foreseeable materials, of something the size of a large destroyer or cruiser or ocean liner. This is entirely out of the question if you look into the relative size of the foils and wing structure that would be required.

So that this cube-square law restricts you to moderate and small-size craft.

I mentioned before that the power-speed relationship is such that you must require high speed to make these at all desirable, because if you are at slow speed and larger size, then you can do the job better with a planing hull, or a conventional ship.

One other minor variation: At least until you get very large—and by that I mean having long enough struts to escape any wave that can come by—the speed and size combination is further limited by the degree of passenger comfort or the degree of acceleration that the material you are carrying can stand. Normally you will design to half-g, or less, and if you do this, you are restricted in the top speed that you can go over any waves, if the waves have to be followed.

So to review our state of the art, I would say that we are confident of building up to 100 tons and going further as the state of the art develops.

We are able to design the foils very accurately, thanks to 50 years worth of aeronautical research that has developed information on airfoils, which is directly applicable.

A word of caution here, however, is that this directly applicable performance of the airfoil ceases when you get to what we call cavitation in water.

I may have mentioned earlier that the principle of operation of these foils is by low pressure on the upper surface and high pressure on the lower surface, induced by flow. Up to certain speeds, say in the order of 40 to 50 knots, depending on the loading and size, water operates just like air, and it follows the general lift pattern. About this point,

however, water starts to break down, and it forms a vapor cavity, after you have reached this low pressure, where the vapor pressure of water becomes significant compared to the pressure you are putting over the foil. When you get this cavity, you get a marked change in the lift and drag characteristics. So that if the airfoil is a conventional shape, similar to an airplane wing, it becomes a very resistful device. It loses some of its lift. Plus the fact that this cavity starts collapsing on you from time to time and does mechanical damage to the surface of the foil, since the collapse is a rather quick operation. So that at this point you must then design to operate in a bubble, and this is what we call supercavitation, which you may have heard of.

If you operate in a bubble, the only magic there is that you change from an airfoil shape to something that approaches the shape of an ax, and you drive it through the water with the sharp edge leading, you pick up a high pressure on the bottom surface; on the top you have nothing but vapor or cavity or vacuum, which extends well beyond the trailing edge of the foil and never collapses on the foil.

This area I will except from our statement of capability of design in the present state of the art. This is an area where we are doing considerable research and will have to do a lot more before we know how this type of foil behaves.

However, this type of foil as well as this type of shape for a propeller blade will be required before we get up into even the lower threshold of what you might call aircraft speeds for these boats.

We are restricted in subcavitating operation, to down in the 50- to 60-knot range, which is very fast for boats of this size, but compared to aircraft, of course it is quite slow.

If I may have the slides back again, please?

Now, I would like to speak just a little to our current programs and those of some of our friends and come back again to the PC—H.

This type of craft, as the admiral has mentioned, tracks down its prey by sitting on the surface. If you will note here, you may not be able to see it, but there is a sonar that has poked its nose out from under the hull and is listening to the submarine. This, not only because of noise but because of structure and other reasons, we can't leave down when the boat picks up speed, so she is sitting quietly in the water, listening, and then gets into this configuration for a high-speed dash to the area of interest, and then your torpedo tubes let go a weapon to the target. This is about 100 tons and about in the 40- to 60-knot area of speed.

Our friends, the Canadians, have been following along in a hydrofoil development (fig. 13), parallel to ours but not duplicating it, for about the same time that we have.

The predecessor of this boat, the R–101—they called it the *Massawippi*—which is a most successful ladder-foil boat, ran up in the 70-knot area, in Halifax, Nova Scotia, was high powered, ruggedly constructed and did well in head seas. It had some stability problems which are inherent in this type of configuration, but the Canadians did a lot of development and they perhaps are the leaders in this type of foil configuration.

This is a picture of the *Bras D'Or*, a 17-ton version of the Canadians' first test craft. This had some growing pains in its first inception but now is operating fairly successfully.

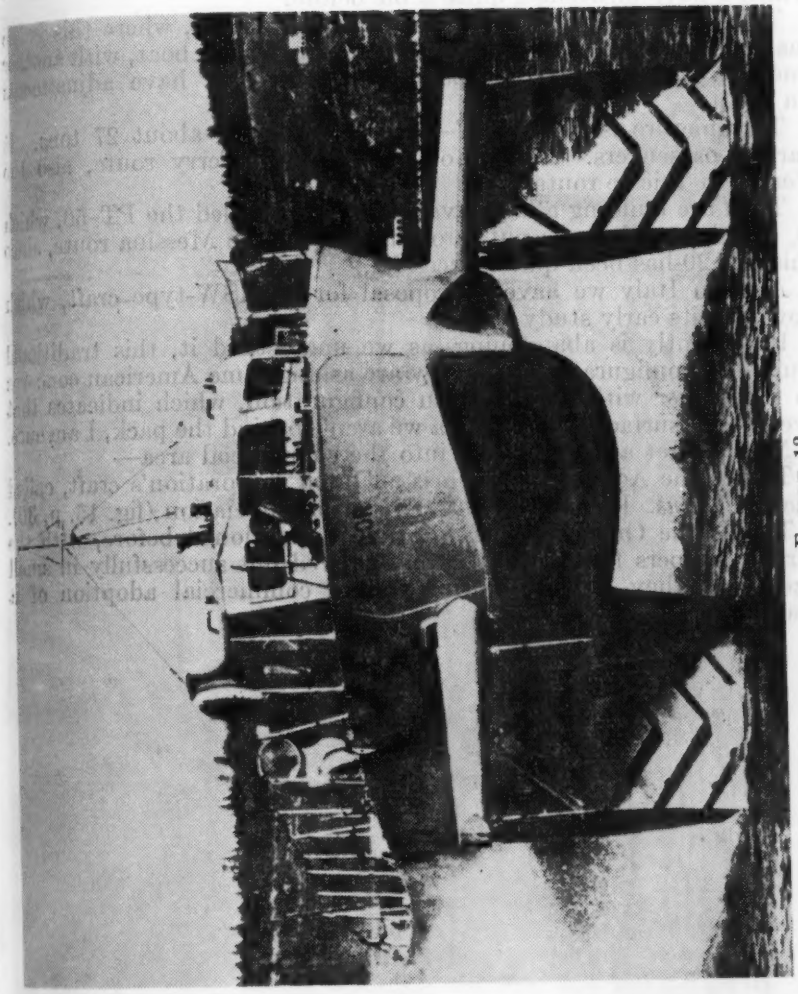


FIGURE 13

The Canadians, from this effort, are planning a much larger craft, again an ASW-type, which would be up in around the 200-ton range.

We have been sitting down with them and discussing the program as it goes along, technically, and they are taking one area, we are taking another, so that the sum-total of both efforts will push the state of the art still further forward.

Here we see a picture of the Von Schertel configuration (fig. 14), which I have mentioned quite a bit before.

This is the typical European-type configuration, where this is the main surface-piercing foil that goes clear under the boat, with another one aft. It is a V-foil type. Sometimes they have adjustments on them.

This picture is of the PT–20 class, which is about 27 tons. It carries passengers. This is on the Messina Ferry route, also the Venice to Trieste route.

They are building a larger version of this, called the PT–50, which is, I understand, to be put into service over the Messina route, since this PT–20 has been quite successful.

Also, in Italy we have a proposal for an ASW-type craft, which now is in its early study stages.

It presently is abandoning, as we understand it, this traditional European configuration, and they are asking some American concerns to come over with an American configuration, which indicates that even in the surface-piercing area we aren't behind the pack, I am sure.

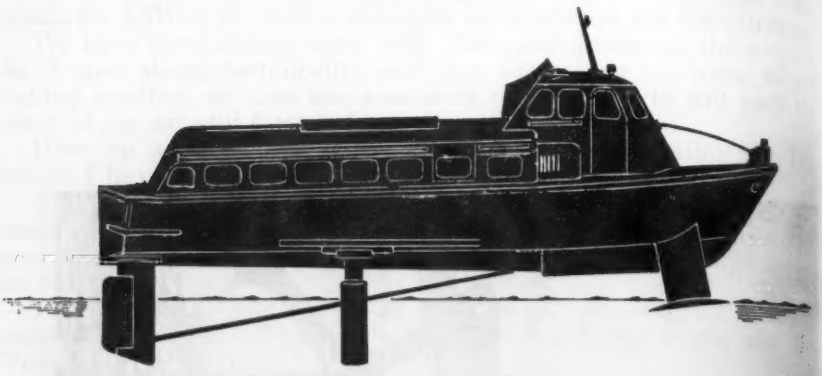
Now, to get a little further into the commercial area—

This is the Aquavion, which is a Dutch corporation's craft, called the *Aqua-Bus*. I think that is the right pronunciation (fig. 15, p. 30).

This is the Grumberg configuration, I mentioned before, with the surface slippers forward. This has proved out successfully in small sizes, and they are attempting to get commercial adoption of it elsewhere.

FIGURE 14

FIGURE 15



This is a rather poor slide of *Raketa* (fig. 16), which is a Russian hydrofoil; has been in commercial service in rivers and harbors, I am told.

You will note it is not precisely the conventional European style. However, it is quite similar in that it has a low hull clearance, with a piercing-type foil system. This does not mean that this is the best the Russians are doing, but this is what we now know about, so that at least they are able to do this much.

We mentioned the parallel effort of the Navy and Maritime Administration. This is a picture of the projected 80-ton Maritime craft (fig. 17, p. 32) which will make 60 knots in its initial version at least.

It has a surface-piercing system not too far different from the European system, although it is much better developed, we hope.

You see, with the Canadian ladder boat and the Maritime in the surface-piercing V-foil boat, and with us in the submerged foil PC—H, we have the front pretty well covered.

This traces a general look at the craft we have gone through, the developments we have gone through, and our final product, if the slide will show, would be a craft that is capable of being modified for higher speed, for various configurations and, of itself, is larger than anything presently underway, to give us what we might call the *Albacore* approach (fig. 18, p. 33).

Following our success in developing the submarine *Albacore* by this method, we figure if we can build a versatile craft in the two to three hundred-ton range, which is now projected, this will be the quickest way to get our technical answers, so that when the operational answers come out of PC—H, there will be no technical lag-time for us to be able to design and put into the water a craft that best meets the specifications required from our operational experience.

That concludes my remarks, sir.

I have about a 10-minute movie clip that shows a number of these craft in operation and reviews a little bit of the hydrofoil, if you have time to see it.

The CHAIRMAN. All right.

We had better rush a little bit, because we want to ask you a few questions, and we do have to get to the floor at noon.

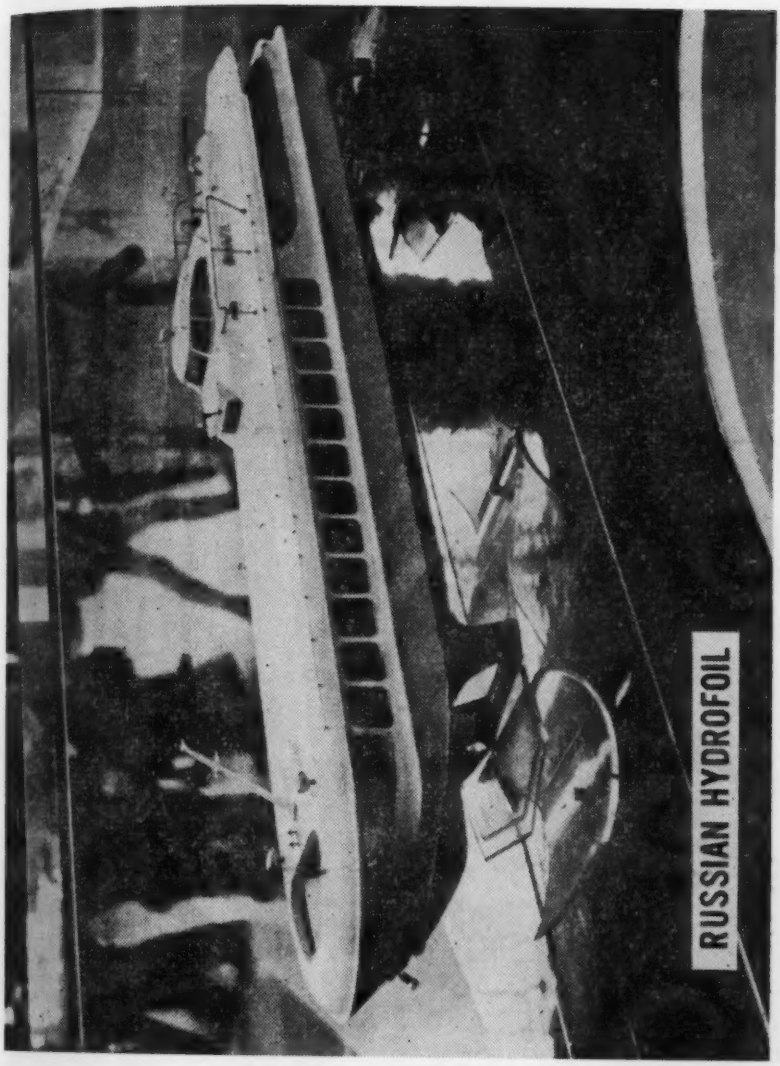


FIGURE 16

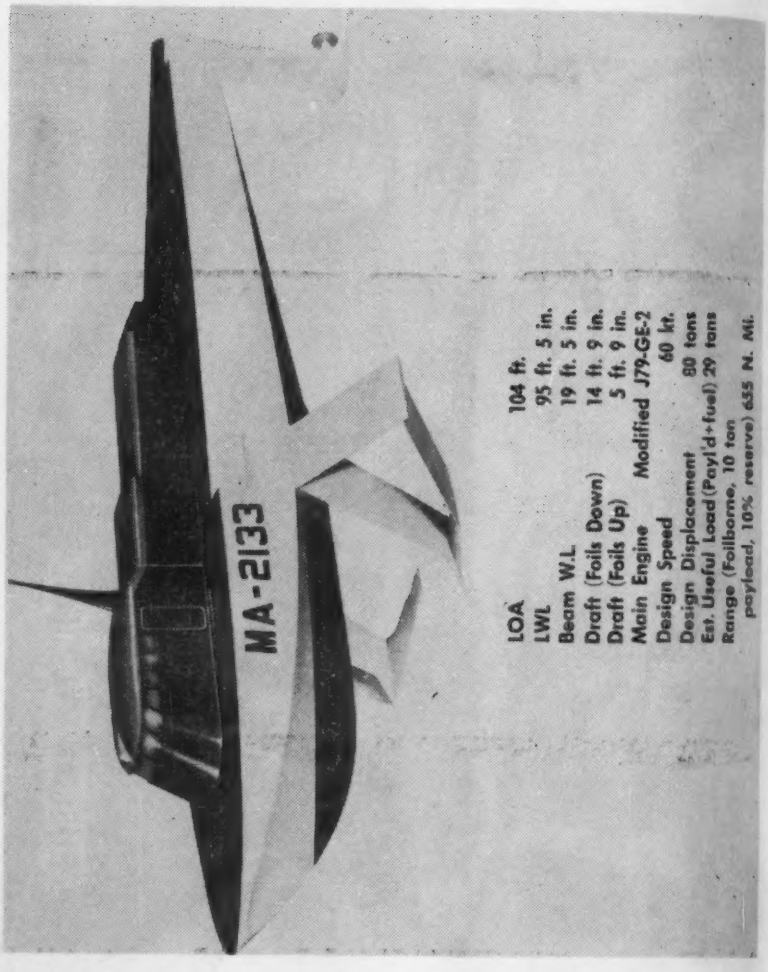
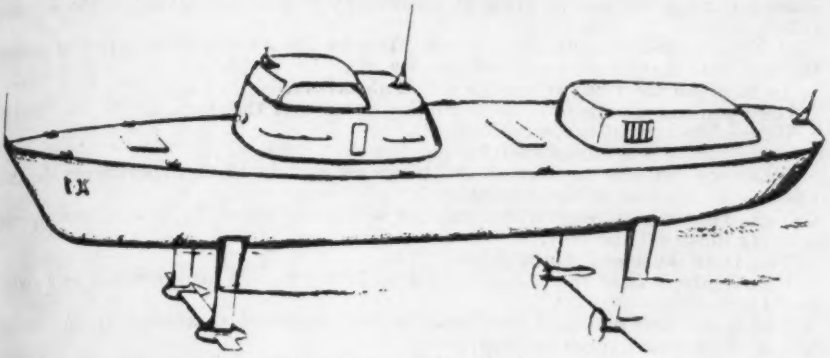

MA-2133
LOA 104 ft.
LWL 95 ft. 5 in.
Beam W.L. 19 ft. 5 in.
Draft (Foils Down) 14 ft. 9 in.
Draft (Foils Up) 5 ft. 9 in.
Main Engine Modified J79-GE-2
Design Speed 60 kt.
Design Displacement 80 tons
Est. Useful Load (Payld+fuel) 29 tons
Range (Foilborne, 10 ton payload, 10% reserve) 655 N. Mi.

FIGURE 17

FIGURE 18



Admiral JAMES. Would you like to make your questions now, and we can have——

The CHAIRMAN. I think it would be better to see these craft in operation. I think everybody would like to see them in operation.

Captain STILWELL. All right, sir.

[Comments on the film.]

This is the Baker boat I mentioned previously which uses the surface-piercing V-foil. By the looks of the foil, she is doing around 30 in the picture.

This shows you the airfoil section of the foil going through the water and how the lift is developed, similar to an aircraft in the air.

This, I might emphasize, is at the moderate speed range.

The CHAIRMAN. As you go along, Captain, could you show us where and how the power is transmitted?

Captain STILWELL. Yes, sir.

This indicates the relative size of an airfoil as against a hydrofoil.

On most of these craft, as mentioned, the power has to come down through these struts into angle drives of various types.

This shows the foil boat in its flying condition.

Here is the Baker boat taking off. You see how the hull is clearing the water.

There she is going through some rough seaway.

This shows you the foil seeking its proper level.

Here is the *D-Alpha-D/T*, which is the Hook configuration.

Here is the electrical control on the test bed.

Here is the *XCH–4* coming in for a landing. This is the one that made about 75.

Here are the two types that I have mentioned.

This again is the V-foil boat coming in for a landing.

This shows you the relative size of the amount of foil required to support the boat. You will see how she is following the waves.

Here she is out of the water.

This shows you the two possible ladders.

This is the Canadian type.

That is the U.S. type on the right.

Here is the XCH–4 flying in a moderate seaway.

You will note how the surface-piercing type, even in a ladder, responds sometimes to a seaway a little more than is desirable.

Here is the test craft I mentioned with an electrical probe operation. As you can see, we didn't have all the bugs out of it.

Here is the mechanical submerged control foils, the Hook system. It is a little hard to see there.

Here is the *Lantern* underway, the Vannevar Bush boat.

This is taken down at Annapolis.

Just a quick review here:

The *Grunberg* has these skis that pin the bow to the water's surface, and the stern is supported by a submerged foil.

In this one the submerged foil is being controlled. A small stabilizer keeps the stern following the bow. Most of the weight of this aircraft is on the forward foils.

Here is the craft up out of the water. You see these levers come down to control the foil. He is operating it there, you see.

To improve the ride, we put on shock absorbers.

Here you can see the propulsion coming down over the stern.

Here is the propeller coming out.

The steering is accomplished by moving that strut.

What we did was to take those things off and in these experiments do this electrically instead of mechanically.

Now, this was totally submerged foil being controlled by that electric probe sticking down off the bow.

This is an outboard motor drive.

Here again is *Lantern*. *Lantern* had an inboard shaft arrangement to a right-angle belt drive.

This is the first one, as I mentioned before, that had an autopilot. All it had was a single-point measurement.

As I said, *Lantern* had a single-point measurement, and then the roll and pitch was handled by autopilot.

These are the universities that have done theoretical work for us.

Now, this shows you what we are combating. You will see the amount of energy that comes out of a conventional boat in terms of wavemaking. This is where we get our 2-to-1 advantage in power.

There is the XCH–4 taking off again. You will note the lack of a wake in this one. You see, behind that craft there is very little wake at all. Actually, it has been shown that you can go into marinas and harbors with these at high speeds without disturbing the moored craft.

Here is the development that has the breakthrough in terms of the measuring device. We are deliberately bringing her through some very rough water here.

Here is a Von Schertel boat, a skimmer, German built, actually a bigger and more powerful one than *Sea Legs*. We brought them out in the same water to show you how *Sea Legs* compared with their boat. You see them go through the same identical water here. This is *Sea Legs* coming through the same thing with submerged foils and control. You see, she has some little change of altitude just to be sure she doesn't kiss the waves, but it is very minor.

I think that is about the end of anything that is significant.

Admiral JAMES. Mr. Chairman, that is our presentation.

The CHAIRMAN. It is very interesting, indeed.

You have been most thorough in handling the presentation, and we are grateful to you.

I don't quite understand the propulsion techniques yet, however.

Is it the conventional type of propulsion—gasoline or oil?

Admiral JAMES. There are many possibilities that need to be explored.

Presently, today, we are making use of the so-called outboard motor type in these smaller craft.

The CHAIRMAN. Transmitted through the foils?

Admiral JAMES. Yes, sir.

This model doesn't show it too well, but these are the engine vents here, with the engines in the hull, and the power is driven through normal shafting, through a set of angle-gears, changed in direction from the horizontal position of the shaft, down through the foils, changed again through a set of angle-gears to come out into the surface to drive the craft ahead.

The CHAIRMAN. You haven't tried using jet propulsion, have you?

Admiral JAMES. We are indeed looking into this.

One of our aircraft companies is looking into a program of what they call Mar-jet, in which we are actually causing a volume of gas or water to be passed through the struts that support the foils. This

is the area of research, where a great deal more work remains to be done.

The CHAIRMAN. Is there a propeller on the rear of the PC—H model?

Admiral JAMES. Yes.

The CHAIRMAN. Have you tried lengthening that propeller to let it drop into the water, regardless of the foils?

Captain STILWELL. This has been done on several craft.

Actually, the Baker boat had a retractible shaft. It came right down from the engine; the whole shaft dropped down with a propeller on the end of it, with just a single strut holding the propeller laterally.

The CHAIRMAN. But considering the state of the art at this time, the use of the standard propeller is probably the best method?

Admiral JAMES. This is the state of the art today, yes, sir.

Captain STILWELL. Yes.

The CHAIRMAN. Now, hydrofoils are in regular use, you say, in passenger service? This country has none in use in passenger service, does it?

Why are we behind the other nations in the use of hydrofoils in passenger service?

Admiral JAMES. This would be a very difficult one to speak to.

The stimulus for this has been largely in the Government service, although quite recently one of the small boat builders and aircraft companies have come out with a "Do it yourself kit," which, when applied to a small craft, will give you the effect of a hydrofoil craft.

I am sure that America has embraced this now, commercially, rather than limiting its potential use to the military.

The CHAIRMAN. So you expect developments in the future that you haven't had in the past?

Admiral JAMES. Yes, sir, very definitely.

The CHAIRMAN. Any questions?

Mr. KING. I have a couple of questions. What would happen if your craft were to encounter a heavy bed of seaweed or a log or some submerged obstacle, perhaps a large fish, shark, or something?

Admiral JAMES. You have done it, haven't you?

Captain STILWELL. Yes, sir.

I can't give one answer for all of them.

We have run over logs and things like this, and usually the log comes out second best.

Seaweed is a little bit happer in its consistency for staying with you. However, with a suitable sweepback, so that there is a little flow out toward the tips of the foils, you are able to shed it in most cases.

Admiral JAMES. The worst that can happen to you is that you would stop flying and become a displacement craft, entangled in the kind of muck that you are speaking of.

Mr. KING. I have another question.

As to the economics of this thing, isn't it possible that when you enter an area of high-speed propulsion you are entering into an uneconomic area as far as watercraft are concerned? In other words, you are competing with other vehicles that are more adapted for speed, and it is uneconomical, in other words, to get a boat up in the air. When you start getting up in the air, let's start using airplanes that are designed for that.

You can double your speed, as you have so eloquently illustrated, but is it not possible that the actual economics of it indicate that you

pay such a penalty for doubling your speed that you actually are competing unprofitably against other craft that are made for higher speeds?

Admiral JAMES. If we were simply enthusiasts for hydrofoils, we would err greatly in trying to push this frontier. There are definite economic limitations to the application of this new technique.

I think Captain Stilwell strove to point out that where speed was in fact a requirement, this is the way to get it. There is only a limited area where such is the fact.

I spoke to the military advantage of the antisubmarine capability of this craft. This I think we can demonstrate very completely when we put this boat to sea here in a couple of years.

I tried to identify a few potential commercial uses where the economics of the thing would justify the added cost that you would involve, such as, for example, if we did have a banana fleet of these things coming out of Central America, we could have a much smaller craft in fact, because you could get your bananas from Central America to American ports in very short time, and hence you wouldn't have to put the heavy investment that you otherwise would in the size of this ship, the power to drive it, all these aspects.

It is not going to compete economically except where high speed is a very important consideration.

Mr. KING. Yet you still need essentially a boat rather than an airplane?

Admiral JAMES. Correct.

Mr. KING. If you put too much emphasis on the speed, you might as well get into conventional aircraft where you can really get speed.

Admiral JAMES. This is correct.

But Commodore Francisco has to trace smugglers on the ocean, and he needs, therefore, a high-speed antismuggler kind of craft.

Mr. KING. This is strictly a specialty item?

Admiral JAMES. It is indeed.

Captain STILWELL. It is a limited application.

The CHAIRMAN. What about on the Mississippi River, where you have to go upstream a great deal? What would be the method in which that would operate? Would the fact that you are above the surface make any difference in the resistance of the stream going upstream?

Admiral JAMES. No, sir.

The CHAIRMAN. It would not be any different?

Admiral JAMES. You might have a little less power requirement going upstream because you have the flow of the river coming down.

The CHAIRMAN. But you would be going up. You would still have to go up against the current.

Admiral JAMES. Right, but you get your lift a little bit cheaper, perhaps.

The CHAIRMAN. Mr. Moeller?

Mr. MOELLER. No questions.

The CHAIRMAN. May I ask you a few questions, then, in reference to this thought:

Will this boat that you are attempting to develop economically in effect operate on legs above the water?

Captain STILWELL. Yes.

Admiral JAMES. Yes.

The CHAIRMAN. And when it is at rest, or in very slow motion, it will operate on the surface, like a normal boat does.

Now, in either event, it will be very close to the surface of the water. Suppose your waves are 30 feet high, how would it operate?

Captain STILWELL. I think the question is on the size of the craft. If you get a large enough craft, it would become feasible, geometrically, to provide legs or struts long enough that you could take a 30-foot sea without rising. This would be a tremendously large craft. But you can operate in a combination of allowing certain size waves to pass under the hull and then, when any wave is larger than that, you follow, so that you would describe the path that would go up, and come on down the other side of the wave.

The CHAIRMAN. Just cut through the tip of the wave?

Captain STILWELL. Ideally, with the least acceleration, you would come down to where the tip of the wave would just brush the bottom of the hull.

The CHAIRMAN. Now, have you made a comparison of this type of craft with the air-pressure ground machine that we had before this committee some time back?

Admiral JAMES. No, sir; we have not in fact gotten equipment of the air-skimmer type of vessel at sea today. We will have here in Washington, I am confidently expecting, early in june, the first such vehicle, which the Navy has financed.

The CHAIRMAN. That is operated on the ground by air pressure?

Admiral JAMES. It is operated on an air bubble, but at sea, over the water.

The CHAIRMAN. Now, the hydrofoilship obtains its lift from the waves, from the water, and its propulsion likewise from the water. But your skimmer machine will get its lift from the air when it is in operation?

Admiral JAMES. Correct.

The CHAIRMAN. And its propulsion from the air?

Captain STILWELL. Maybe water. It depends.

Admiral JAMES. We have two or three projects in this so-called ground effects vehicle program, one using a water curtain that would be deflected to give the propulsive power. But air or water would be our medium.

The CHAIRMAN. In your skimmer machine, you are following the ground effect development?

Admiral JAMES. It is exactly that.

The CHAIRMAN. Now, have you reached a point where you can see, in the present state of the art, whether it is better to use the hydrofoil type of operation or the skimmer or ground-effect type operation?

Admiral JAMES. I think we are really talking about fruit, but of the banana and apple character here, sir.

The hydrofoil craft has certain specific applications that are limited, as we see the state of the art today, to something in the order of 300, possibly 400 tons maximum.

In the air-supported vehicle, we are looking already at 2,000-ton craft, although we have many, many problems to solve before we can get there.

So the potential of collision between these are no more important than the potential between small boats today and aircraft carriers today. They have different uses.

The CHAIRMAN. This type of operation you have presented today is a small-craft operation?

Admiral JAMES. It could be called a small-ship operation in contrast to the potential of large-ship operation.

The CHAIRMAN. And, as you told our colleague, Mr. King, it is a specialized type of craft?

Admiral JAMES. Yes, sir.

The CHAIRMAN. Whereas your ground-effect operation could be used in very large-type operations?

Admiral JAMES. This is the potential, sir.

We have not of course breached these frontiers yet. We are simply at the threshold.

The CHAIRMAN. However, the ground-effect operation is not yet in commercial use, whereas, this is?

Admiral James. This is correct.

The CHAIRMAN. And you envision a need for both of them?

Admiral JAMES. Yes, sir.

Mr. MOELLER. Would the Chairman yield?

The CHAIRMAN. Yes.

Mr. MOELLER. When you speak of the larger craft, do you mean transoceanic?

Admiral JAMES. We could sit here and dream ultimately of transocean ships carrying important and impressive payloads. Some of the more parochially inclined people who are enthusiasts are talking about aircraft carriers on the ground-effects principle. This kind of imagination has to be proven first by some real hard work to get there.

The CHAIRMAN. Then the craft you are now talking about would not take us over to the commodore's island in 4 days?

Admiral JAMES. Yes, sir. However, I would be pleased to meet him there, having gone there by air, and meet him on arrival. [Laughter.]

The CHAIRMAN. You would certainly check the weather before you let a good friend like the commodore get out in this type of sea operation, wouldn't you?

Admiral JAMES. Yes, sir, indeed.

The CHAIRMAN. So, actually, this would be limited largely to operations near shore, or in between islands?

Admiral JAMES. No, sir, not quite that, because you have always got a boat.

The CHAIRMAN. But you have a small ship.

Admiral JAMES. A 110-foot ship is relatively a large ship, and many smaller have crossed the oceans, but you have lost the advantage of high speed, of course, when you assume that attitude.

The CHAIRMAN. So it is, in effect, a continuous high-speed capability that you are giving that boat?

Admiral JAMES. Yes, sir.

The CHAIRMAN. Now, what amount of money are you spending on that?

Admiral JAMES. This particular ship is $4.8 million for the construction and finalization of design of this ship.

The CHAIRMAN. That is for the fiscal year 1961?

Admiral JAMES. It is in the fiscal year 1960 shipbuilding program.

The CHAIRMAN. You will finish it this year?

Admiral JAMES. No, sir. That is when it was authorized by the Congress. We have not yet awarded the contract for construction.

The CHAIRMAN. How long will it take to construct?

Admiral JAMES. We are estimating it will take about 2 years plus to get this ship completely designed and built.

The CHAIRMAN. So about the year 1962 you will have one ship?

Admiral JAMES. Yes, sir.

The CHAIRMAN. For use?

Admiral JAMES. Yes, sir.

The CHAIRMAN. And that will be a research ship?

Admiral JAMES. No, sir.

You see, this is in fact an operational ship. It is being equipped with weapons, and it is to test the operational questions and capabilities of this craft.

The CHAIRMAN. You talked about one research ship.

Admiral JAMES. Yes, sir.

The CHAIRMAN. But that is not in the mill at this time?

Admiral JAMES. It is in the mill in the sense that it is a specific program in the Bureau of Ships. It has the Chief of Naval Operation's endorsement and for which we are seeking funds by one means or another.

The CHAIRMAN. So you will have, in 1962, the PC—H.

Admiral JAMES. Yes, sir.

The CHAIRMAN. And you will also, perhaps, have in development the research ship that you have in mind?

Admiral JAMES. That is exactly the program we are advocating.

The CHAIRMAN. That is the extent of the program?

Admiral JAMES. Yes.

The CHAIRMAN. Of course, if that provides a high-speed means of detecting, running down and destroying submarines, I am sure the Navy will show more interest in the program.

Admiral JAMES. In fact, our next year shipbuilding program will recommend the partner for this one in order to exploit this grasshopper operation technique.

The CHAIRMAN. That ship has what speed?

Admiral JAMES. This ship will have no less than 45 knots, and we are hopeful that it may be finally developed to give us up to 60 knots.

The CHAIRMAN. That would be arround 72 miles an hour.

Admiral JAMES. This is the order of statute miles.

The CHAIRMAN. And that ship would weigh about 100 tons?

Admiral JAMES. Yes, sir.

The CHAIRMAN. And what crew will it carry?

Admiral JAMES. It will have a crew of roughly 12 people on board for the warship functions that it will perform.

The CHAIRMAN. It will operate with sonar?

Admiral JAMES. Yes, sir. It will have two different kinds of sonar, one that will be extended below the hull on a fixed arm to do certain listening above the thermal layer, and then it will have what we call a variable-depth sonar in which we allow cable to pay out, with the transducer, below the thermal layer, for improved sonar potential.

The CHAIRMAN. I think that is all the questions I have.

Any further questions?

(No response.)

The CHAIRMAN. Counsel has two questions here.

He says there has been recent mention of submersible hydrofoil boats.

Has much been done in this respect?

Admiral JAMES. I will have to pass that one to Captain Stilwell.

Captain STILWELL. This general idea has come up many times in the past years.

The general state of the art, powerplants, weights being what they are, we have always found, no matter how radical the proposal, that the hydrofoil principle and the submarine are muchly exclusive. I won't say that some genius won't figure out how to do it, but at present it would be like trying to fly an elephant.

The CHAIRMAN. So we have made very little progress on that?

Captain STILWELL. Practically zero, sir.

The CHAIRMAN. You mentioned new metal development. What about that in reference to this project?

Captain STILWELL. Of course, the efficiency of these boats will improve; the thinner you can make the struts or the legs, and the thinner you can make the foils, as you get stronger materials, it will either permit your present boats to go faster or permit you to build larger boats to about the same configuration you now have.

The CHAIRMAN. You might resort to the use of aluminum more than you do now in the construction of ships.

Captain STILWELL. Well, in the strength area, in the hull area, we are already well into aluminum, and in fact, this will have to be a marriage of ship and aircraft technology. In the foils and struts, we are well beyond the strength limitation of aluminum.

The CHAIRMAN. It might be beyond the strength limitations of steel.

Captain STILWELL. This is a possibility, and this is why I mention the size limitation looming on the horizon somewhere.

The CHAIRMAN. Well, you have a most interesting development there, and this committee will watch this development with a great deal of interest, and at least a part of the enthusiasm the admiral has shown in presenting this to us.

Mr. Hines, do you have any further questions?

Mr. HINES. No sir.

The CHAIRMAN. Admiral, do you need any assistance from the committee?

Admiral JAMES. At this moment, our purpose was just to show you what was underway.

Our assistance is amply available to us, presuming we shall convince our associates in the Department of Defense of the need for this research development. We think we have them on the hook.

The CHAIRMAN. We will get out a strong committee report, then, to perhaps assist.

Admiral JAMES. This would be helpful.

The CHAIRMAN. Perhaps Mr. Hines may call upon you, Admiral, or Captain Stilwell, either one, because this has been a very brief hearing. We have only skimmed along the surface, so to speak, with that type of project. If he does, we would appreciate very much your cooperation.

Admiral JAMES. We assure you of this.

The CHAIRMAN. If there is no further business the subcommittee will adjourn until tomorrow morning at 10 o'clock.

(Whereupon, at 11:53 a.m., the subcommittee adjourned, to reconvene at 10 a.m., on Tuesday, May 24, 1960 on another subject.)

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